Traffic-related mortality in industrialized and less developed countries

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Road traffic-related mortality has traditionally been regarded as a problem primarily of industrialized countries. There is, however, growing evidence of a strong negative relationship between economic development and exposure-adjusted traffic-related death rates. Cross-sectional data on road traffic-related deaths in 1990 were obtained from 83 countries. The relationship between such mortality and a number of independent variables was examined at the individual country level by means of multiple regression techniques. These were also used to elucidate factors associated with variations in age, sex, and case-fatality patterns of road traffic mortality. Countries were grouped according to region and socio-economic features, and the mortality data were summarized by these groups.

The gross national product per capita was positively correlated with traffic-related mortality/100 000 population/year ($P=0.01$), but negatively correlated with traffic deaths/1000 registered vehicles ($P<0.0001$). Increasing population density was associated with a proportionately greater number of traffic-related deaths in the young and the elderly ($P=0.036$). Increasing GNP per capita and increased proportional spending on health care were associated with decreasing case-fatality rates among traffic-accident victims ($P=0.02$ and 0.017, respectively).

Middle-income countries appear to have, on average, the largest road-traffic mortality burden. After adjusting for motor vehicle numbers, however, the poorest countries show the highest road traffic-related mortality rates. Many industrialized countries would appear to have introduced interventions that reduce the incidence of road traffic injury, and improve the survival of those injured. A major public health challenge is to utilize this experience to avoid the predicted increase in traffic-related mortality in less developed countries.

Introduction

Global patterns of disease have frequently been characterised by their predominance in either the developed or developing world (*4*). Thus, communicable and nutrition-related diseases are common in developing countries while degenerative and "life-style" diseases occur mostly in industrialized countries. Any orderly transition from diseases of under-development to those of development is, however, increasingly being questioned. Emerging data suggest that many "diseases of development" are now occurring in poor countries in addition to their existing burden of poverty-related diseases. In fact, the incidence rates of diseases commonly associated with industrialized countries are often higher in the developing countries (*11*).

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Road traffic accidents (RTAs), and related injuries, tend to be under-recognized as major health problems in developing countries (*15, 16*). However, the World Bank's *World development report* (WDR) for 1993, in a review of the global burden of disease, highlighted the worldwide burden of traffic-related injuries and mortality, emphasizing their importance in less developed countries (*11*). Among males in the economically active age group, motor vehicle injuries are considered to be the third most important cause of death in developing countries, the first two being tuberculosis and HIV/AIDS. Aside from the significant health burden, traffic crashes and collisions are estimated to cost the less developed countries between one and two percent of their gross domestic product annually; most of this results from property damage (*1*). Furthermore, while these rates are decreasing in most industrialized countries, they appear to be increasing in many less developed countries. Road traffic mortality increased by more than 200% in African countries and by 150% in Asian countries between 1968 and 1983, while they decreased by more than 20% in Europe over the same period (*5*).

Smeed was the first to relate road fatalities to other national statistics (*6, 7*). He found an inverse exponential relationship between deaths per vehicle and vehicles per capita in a cross-sectional sample of 20 countries in 1938. Subsequent analyses of data from different countries have confirmed this relationship. They have also shown relationships between road fatalities and national wealth, vehicle density, population per hospital bed, and population per physician in cross-sectional data sets (*3, 9, 10*).

WHO's World Health Day in 1993 focused on preventing violence and negligence, and reiterated the importance of recognizing the public health burden of injuries and the need for appropriate interventions. There is now excellent evidence, primarily from industrialized countries, that road-safety-related interventions can be extremely effective and may contribute to a reduction in mortality, morbidity and disability.

This article reviews the current global and regional patterns of traffic-related mortality, and examines the relationship between traffic-related mortality rates and case-fatality rates, including age and sex-specific data, with selected socioeconomic, geographic, demographic and health care characteristics of the countries studied.

Methods

Cross-sectional data on the numbers of traffic-related deaths and injuries were obtained for 1990 from 83 countries. Where 1990 data were not available, data from the closest preceding or subsequent year were used. The countries studied (listed under the country groups used for the summary statistics) and the year of data are shown in Table 1. As part of the World Bank-initiated review of the global burden of disease, the Overseas Unit of the Transport Research Laboratory, working with the London School of Hygiene and Tropical Medicine, conducted a postal survey to national road safety organizations worldwide. The questionnaire requested information on the numbers of traffic-related deaths and injuries, by sex and broad age groups.

The data returned (from 46 countries) were supplemented by data routinely published by the International Road Federation (IRF) (*2*). A number of other published sources, such as national road traffic safety reports, were used to complete the available data. Countries with a population of less than one million were excluded because of wide variations in

Table 1: **Countries or territories for which data were obtained on at least total road traffic-related mortality, number of vehicles per capita, and GNP per capita (all information from 1990 unless otherwise stated)**

Africa (AFR)	Asia (AS)	Latin America (LAM)	Middle East (ME)	Former Socialist East European Economies (FSE)	Industrialized countries (IND)
Algeria	Hong Kong	Brazil	Egypt[a]	Albania[a]	Australia
Benin	Indonesia	Chile	Iraq[a]	Armenia	Austria
Botswana	Republic of Korea	Colombia[a]	Israel	Bulgaria	Belgium
Central African Republic	Lao People's Democratic Republic	Costa Rica	Jordan[d]	Czechoslovakia	Canada
Congo[d]		Ecuador[c]	Kuwait[a]	Estonia	Denmark
Ethiopia	Malaysia[a]	Honduras	Syria	Hungary	Finland
Ghana[a]	Pakistan[b]	Jamaica	Turkey	Latvia	France
Kenya	Papua New Guinea	Mexico	Yemen	Lithuania	Greece
Lesotho	Philippines[b]	Trinidad		Poland	Ireland
Madagascar	Singapore			Romania[d]	Italy
Malawi[a]	Sri Lanka			Ukraine	Japan
Mauritius	Thailand				Netherlands
Morocco					New Zealand
Niger[b]	**India**				Norway
Rwanda					Portugal
South Africa	**China**				Spain
Togo[b]					Sweden
Tunisia[a]					Switzerland
Zambia					United Kingdom
Zimbabwe					USA
					West Germany

[a] 1989. [b] 1988. [c] 1987. [d] 1991.

RTA fatality figures over short periods (one year). The number of vehicles and road density statistics were obtained from the IRF yearbook. Vehicle statistics do not include two-wheeled vehicles because of differences in policy with regard to their registration. Other routine statistics were obtained from the World Bank's *World development reports* for 1992 and 1993 (*11, 12*).

Non-fatal injury figures were also collected, but are not presented here. Poor access to health and police services and rudimentary recording systems are likely to have underestimated non-fatal injuries more than fatal ones, especially in poorer countries (*13*). It is intended that a more comprehensive description of the data gathered will be published elsewhere, and non-fatal injury statistics are used here only to facilitate calculation of the case-fatality index.

Data were analysed using multivariate regression techniques. The total mortality rate outcome (dependent) variables used were crude traffic-related deaths per 100 000 population per year and traffic-related deaths per 1000 registered vehicles per year. Explanatory (independent) variables used were the number of vehicles per capita, road density (km of road/km^2), total surface area (km^2), gross national product (GNP) per capita per year (US$ for 1990), health expenditure as a percentage of gross domestic product (GDP), and population density (pop/km^2).

Previous exercises of this type have used vehicles per capita as an independent variable in regression equations. In this sample we found that vehicle numbers were so closely correlated with GNP per capita (bivariate Pearson correlation coefficient = 0.93) that problems of multicollinearity arose when they were entered simultaneously. This is not surprising, and some national censuses now use vehicle ownership as a proxy variable for wealth. For this reason, vehicle numbers have been expressed in the denominator of the dependent variable, or used to derive an adjustment factor for the independent variable, prior to running the model.

To examine deaths in young economically active persons, the mortality rate of those aged 15–44 years was divided by that of the total population to obtain a ratio of mid-age to total population mortality rates. Similarly a ratio of male/female mortality rates and a case-fatality index (fatal injuries as a proportion of all injuries) were constructed. These were treated as dependent variables in three further regression models using the independent variables mentioned above. In the case of male/female mortality ratios, an additional independent variable, the ratio of female to male secondary school pupils, was inserted in an attempt to capture differences in gender empowerment which would in turn be reflected in differential exposure to motor vehicle travel. The majority of variables were significantly right-skewed and were thus log-transformed (to base 10) before insertion into the model. Those not log-transformed have been indicated as such in Table 2. Computation was performed using the Statistical Package for the Social Sciences (SPSS) for Windows, version 5.1.

All available data were used in the analyses: for some variables, however, data were lacking for some countries. This was a particular problem for the age and sex-specific analyses. The number of countries used is presented for each of the models.

Results

Regional death rates

Fig. 1 depicts, by means of a boxplot, the average death rates per 100 000 population and per 1000 registered motor vehicles by country grouping. The horizontal lines indicate the unweighted arithmetic means for each group; blocks represent the interquartile range, and whiskers the rest of the range, excluding outliers. Outliers are defined as those values lying more than 1.5 box-lengths above or below the upper or lower edges of the box respectively.

The Former Socialist East European nations (FSE) had, on average, the highest road traffic-related mortality rates and the widest range of all the country groupings. Countries in Africa, Asia, and Latin America generally had lower rates than those of developed countries. Developing countries, particularly India and countries of Africa showed substantially higher death rates/1000 vehicles/year and a wider range of values. There is remarkable homogeneity in the rates among the industrialized countries, ranging from 0.17 deaths/1000 vehicles in Norway to 1.28 deaths/1000 vehicles in Portugal.

We also examined RTA deaths as a percentage of all deaths for the six country groupings. These percentages generally showed a similar pattern to that for death rates/100 000 pop./year. For almost all countries, traffic-related deaths accounted for between 0.5% and 3% of recorded deaths for all age groups combined.

Regression analyses

Regression results of RTA mortality rates are presented in Table 2. When crude rates are used without adjusting for the number of vehicles (model A), the model has some predictive power, yielding an R^2 of 27%. The only independent variable that contributes significantly is GNP per capita, which is positively associated with increasing death rates. However, examination of a bivariate scatterplot of GNP per

Table 2: **Regression analysis results of RTA mortality rates**

Dependent variable	Independent variables	Beta value	*P*-value	Model R^2
Model A	Road density	3.47 (3.09)[a]	0.26	
Deaths/100 000	Health exp. (% GDP)[b]	–0.59 (0.55)	0.29	
pop./year[b]	Area	0.21 (1.35)	0.87	**0.27**
(*n*=66)	**GNP/capita**	5.12 (1.95)	**0.01**	
	Pop. density	–2.79 (2.66)	0.30	*P* = **0.0013**
Model B	Road density	–0.30 (0.16)	0.06	
Deaths/1000	Health exp. (% GDP)[b]	0.02 (0.03)	0.53	
vehicles/year	Area	–0.05 (0.07)	0.47	**0.75**
(*n*=60)	**GNP/capita**	–0.72 (0.11)	**<0.0001**	
	Pop. density	0.26 (0.14)	0.06	*P* **<0.0001**
Model C	Road density	0.19 (0.105)	0.08	
15–49-year age	Health exp. (% GDP)[b]	–0.04 (0.022)	0.12	**0.45**
group/total pop.	Area	0.05 (0.088)	0.57	*P* = **0.012**
mortality rate	GNP/capita	0.07 (0.057)	0.26	
ratio[b]	**Pop. density**	–0.19 (0.086)	**0.036**	
(*n*=28)				
Model D	Female educ. index[b]	0.005 (0.003)	0.14	
Male/female	Road density	0.54 (0.47)	0.26	
mortality rate	Health exp. (% GDP)[b]	–0.12 (0.12)	0.33	0.35
ratio[b]	Area	0.19 (0.25)	0.46	*P* = 0.14
(*n*=26)	GNP/capita	–0.31 (0.45)	0.50	
	Pop. density	–0.14 (0.37)	0.70	
Model E	Road density	0.006 (0.14)	0.97	
Fatality index[b]	**Health exp. (% GDP)**[b]	–0.06 (0.025)	**0.017**	**0.49**
(*n*=65)	Area	0.088 (0.061)	0.15	*P* **<0.0001**
	GNP/capita	–0.21 (0.087)	**0.020**	
	Pop. density	–0.03 (0.12)	0.80	

[a] Figures in parentheses are the standard errors of the Beta value.
[b] These variables were not log-transformed; all others were.

capita with death rates (Fig. 2) reveals what appears to be an initially positive relationship which becomes negative at higher levels of GNP. To illustrate this, a best-fit cubic regression function has been superimposed on the plot, and yields a substantially higher R^2 than the linear model (0.41 versus 0.27). The cubic regression formula was as follows:

$$\text{Deaths/100 000 pop./year} = 103\text{–}124\ (\text{LGNP}) + 48\ (\text{LGNP})^2 - 5.5\ (\text{LGNP})^3$$

where LGNP = $\log_{10}$ GNP per capita/year

If the number of motor vehicles are introduced into the denominator of the dependent variable (model B), the predictive power of the model improves substantially ($R^2 = 0.75$). GNP per capita is still the only variable making a significant contribution, but in this instance it is strongly negatively correlated with traffic-related mortality rates. Using a simple bivariate model, the relationship between mortality rates and GNP/capita can be expressed by the formula:

$$\text{Log deaths/1000 vehicles/year} = -0.80 \times (\text{log GNP/cap}) + 2.87$$

Fig. 3 shows an unadjusted scatterplot of GNP/capita versus deaths/1000 vehicles, both scales being log transformed. The linear regression line, and 95% confidence limits for the sample have been superimposed on the plot, and illustrate the strong negative correlation between the two variables. Outlier countries are Togo and the Republic of Korea on the high side, and Madagascar on the low side.

Model C looks at the ratio of death rates in the age group 15–49 years to those in the total population. Only population density makes a significant contribution to the model, the more densely populated countries being associated with a relative increase in deaths in children and the elderly. In model D, none of the variables entered appeared to offer an explanation for sex differences in mortality. The small sample size for this model (n=25) may be partly responsible for this. Model E suggests that both increasing health expenditure and increasing GNP

Fig. 1. **Mortality rates from road traffic accidents, by country grouping: deaths per 100 000 population per year and deaths per 1000 registered vehicles per year.** AFR, Africa; AS, Asia; FSE, Former Socialist East European economies; IND, Industrialized countries; LAM, Latin America; ME, Middle East.

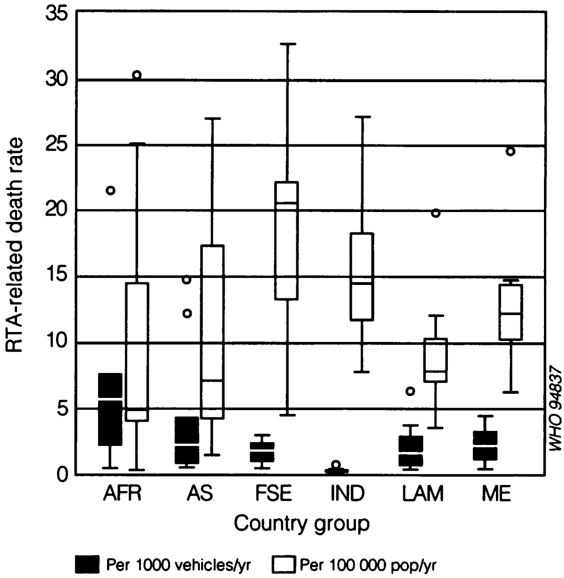
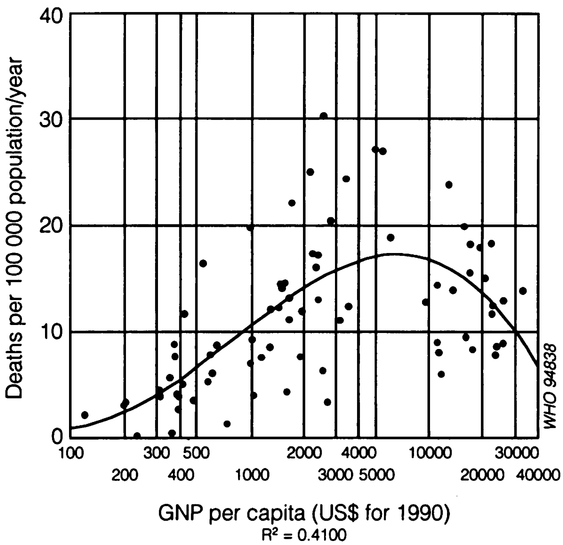


Fig. 2. **Relationship between traffic-related mortality rates per 100 000 population/year and per capita GNP for individual countries (GNP per capita displayed on a log scale).**



per capita contribute to increased survival of those injured in traffic crashes and collisions.

Discussion

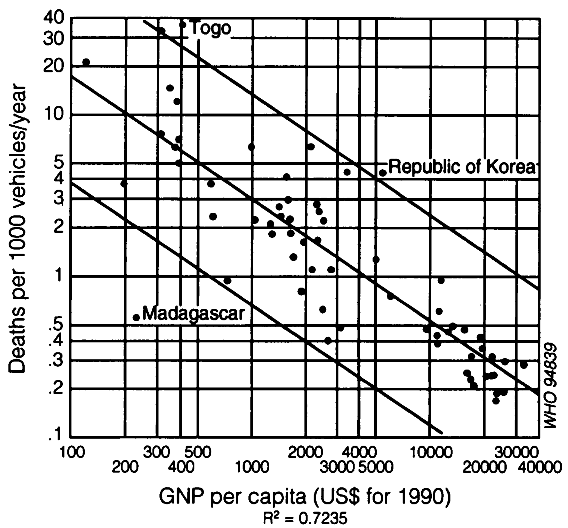
Injury, including road traffic-related injuries and deaths, is frequently underestimated as a major public health problem (*15, 16*). Yet, there are many avenues open for effective interventions.

Cross-sectional ecological studies pose difficulties of interpretation. This is principally because routinely available explanatory variables are made up of multiple components, and are confounded with many factors that are difficult to measure and control in the analysis. A number of specific limitations should be borne in mind in interpreting the results.

The dataset used here, as is the case with similar studies published previously (*6, 7, 9, 10*), makes use of a convenience sample of countries, which may not be globally representative or generalizable. Nevertheless, the fact that the countries studied constitute 79% of the world's population (57% if China, for which some data are missing, is excluded) suggests that the potential for bias is limited. Furthermore, for all of the country groupings except the FSE group, the countries studied contain at least half of the group's total population.

Population-weighted figures have not been used in the grouped or regression analyses. There are two advantages to this approach. Firstly, it avoids global estimates being dominated by countries with large

Fig. 3. **Relationship between traffic-related mortality rates per 1000 vehicles/year and per capita GNP for individual countries (both axes make use of log scales).**



populations, such as China and India (in this analysis they would be responsible for approximately 50% of the input data). Secondly, since many policies to reduce traffic-related deaths operate (or fail to operate) at a national level, and are exclusive to the country concerned, it is appropriate to use countries, rather than persons, as the units of analysis. This is subject to all countries having stable estimates for death rates, hence our decision to exclude countries with fewer than one million population.

Data on the number of vehicles also have their limitations: they do not include two-wheeled vehicles, for example. Countries have different patterns of motorization: in Algeria, Brazil, Botswana, Chile and Kenya cars and light commercial vehicles comprise 60% of motorized vehicles, whereas in India, Indonesia, Thailand and Pakistan motorized two-wheelers predominate (*14*). In countries such as Indonesia, over a third of fatalities occur among drivers of two-wheeled vehicles. The unavailability of data on two-wheeled vehicles will artificially raise the level of fatalities/1000 vehicles.

Furthermore, motor vehicle distances travelled would have been a better exposure variable than the number of motor vehicles, but these data were not available for the vast majority of countries. In addition, no indication of the condition of national vehicle stock are available: it is therefore impossible to know precisely how many of the registered vehicles are actually on the roads and to determine their state of roadworthiness. Under-reporting of events is likely to be more of a problem in respect of casualties rather than deaths: this would have exaggerated the relationship between underdevelopment and high case-fatality rates (*14*). We would have liked to include other possible explanatory variables in the analysis, such as national levels of alcohol consumption, road maintenance expenditure, and availability of, and access to, accident and emergency services, but such data were not available to us.

In addition, information on whether victims were pedestrians or car occupants would have been extremely valuable. Existing evidence suggests that figures for these differ widely between developing countries (with pedestrians ranging from 55% of road traffic fatalities in Iraq to 5% of fatalities in Yemen (*14*)), and little is known about the cause of these differences. Our data were unable to capture any of the marked differences which are known to exist between urban and rural areas: in Chile 89% of reported traffic accidents are in the urban areas, and in Thailand about two thirds occur in Bangkok alone (*14*). Information on the rate of change of GNP, size of motor vehicle stock, road surface area, and a number of other variables may have been useful in examining whether sudden increases in risk factors have corresponding knock-on effects on road-traffic-related mortality rates. Reliable data on these are available almost exclusively for industrialized countries, however, and their inclusion would have limited the analysis to a far smaller group consisting largely of wealthy countries.

To summarize the results of models A and B, it would appear that the poorest countries have highest levels of traffic-related mortality when exposure, as measured by the number of motor vehicles, is taken into account. Traffic-related mortality, however, is highest in absolute terms (i.e., crude rates) in middle-income countries (Fig. 2). This pattern disappears once adjustment for vehicle numbers is made. While causality is difficult to infer from cross-sectional and ecological studies, it seems plausible that increasing national wealth gives rise to an associated disproportionate increase in the number of motor vehicles at lower levels of GNP per capita, and that once countries reach around the $US 5000/capita/year mark, the vehicle numbers level off. In addition, wealthier countries appear to have developed effective means of reducing traffic-related fatalities: this is evident from a wide range of countries over the last two decades. In their earlier work, Jacobs & Cutting showed that almost all the industrialized countries they examined had shown marked reductions in fatalities per vehicle in the 1980s compared with preceding decades (*3*).

The association observed between population density and increased traffic-related mortality among children and the elderly has not, to our knowledge, been reported elsewhere. One hypothesis is that these age groups are more likely to be injured as pedestrians, and that pedestrian injuries are more likely in more crowded areas. Since we were unable to discriminate between pedestrian and motor vehicle occupant victims, this hypothesis cannot be tested on this dataset. Developing countries tend to have far higher ratios of male to female licensed drivers than developed ones, and we might have anticipated a correlation between high ratios of male to female mortality rates, and low GNP per capita. This could have been compensated for by higher exposure of females as pedestrians or passengers in the less developed countries. The small sample size for this analysis is likely to be at least a partial explanatory factor. The case-fatality index appears to decrease with increasing GNP and increases in the proportion of GDP spent on health. While it is intuitively appealing to take this association at face value, some of it may be due to better reporting of casualties in countries that are wealthier and/or have better-established health services.

If cross-sectional analyses such as this one have value in predicting trends in individual countries over time, then increases in wealth among the poorest countries are likely to be associated with large increases in traffic-related mortality in the short term. Fig. 2, for example, suggests that many countries are likely to increase their fatality per 100 000 population rates to between 20 and 30 with increasing GNP per capita, before declining again to levels of around 10 or fewer deaths per 100 000 population. Research is required on how to develop mechanisms to stem the predicted tide and to introduce public health and road safety measures which will draw countries towards the 'best case' scenario, given a certain level of development and availability of vehicles. Such interventions would need to be seen as reasonably cost-effective if they are to stand a chance of being adopted and implemented.

In addition, more focused etiological studies in developing countries should be considered. These have been few and far between up until recently, and exemplify the widespread belief that accidents of any kind are "acts of God", in some way beyond the ambit of formal epidemiological study. These studies would lead to pilot and large-scale intervention trials. There are many lessons about road traffic accidents that developing countries do not have to relearn for themselves (*8*). Improved design, construction and maintenance of roads and vehicles (*5*), the use of safety belts, use of helmets by motor-cycle and bicycle riders, controlling the use of alcohol and drugs among drivers (and, with more difficulty, among pedestrians), enforcement of speed limits, improving the quality of public transport vehicles and their drivers, and use of reflective clothing are likely to be effective in most areas of the world. Cost-effectiveness of these options has not yet been widely evaluated in poorer countries, however, and would be of value to policy-makers. Examination of countries which have significantly more, or significantly fewer fatalities than predicted for their numbers of vehicles and GNP per capita, will be extremely informative. One likely lesson is the need for strong multisectoral involvement and the promotion of healthy public policy rather than a focus on one sector alone, such as the transport sector. Multilateral and bilateral support is needed to facilitate the widespread trial and evaluation of a variety of interventions.

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Résumé

Mortalité associée à la circulation routière dans les pays industrialisés et les pays moins développés

La mortalité associée à la circulation routière est traditionnellement considérée comme un problème des pays industrialisés. Il semble toutefois de plus en plus qu'il existe une forte relation négative entre le développement économique et les taux de mortalité liés à la circulation routière, une fois corrigés de l'exposition. Les données transversales sur le nombre de tués sur la route en 1990 ont été obtenues pour 83 pays. La relation entre cette mortalité et un certain nombre de variables indépendantes a été examinée pour chaque pays par des techniques de régression multiple. On a également utilisé ces données pour élucider les variations de la mortalité en fonction de l'âge et du sexe, et les taux de létalité. Les pays ont été regroupés par région et par caractéristiques socio-économiques, et les données de mortalité ont été récapitulées pour ces groupes.

Le produit national brut par tête était corrélé positivement avec le nombre de tués sur la route/100 000 habitants/an ($p=0{,}01$), mais négativement avec le nombre de tués sur la route/1000 véhicules immatriculés ($p<0{,}0001$). La densité de population était associée à une augmentation proportionnelle du nombre de tués sur la route chez les jeunes et les personnes âgées ($p=0{,}036$). L'augmentation du PNB par tête et l'augmentation proportionnelle des dépenses de santé étaient associées à une diminution des taux de létalité parmi les victimes d'accidents de la route ($p=0{,}02$ et 0,017 respectivement).

Il semble que les pays de revenu intermédiaire aient en moyenne la plus forte mortalité associée à la circulation routière. Toutefois, après correction du nombre de véhicules à moteur, les pays les plus pauvres ont le plus fort taux de mortalité par accidents de la route. Il semble que de nombreux pays industrialisés aient pris des mesures qui réduisent l'incidence des blessures dues aux accidents de la route et qui améliorent la survie des blessés. Il serait du plus haut intérêt, du point

de vue de la santé publique, d'utiliser cette expérience pour éviter l'augmentation prévue de la mortalité due aux accidents de la route dans les pays moins développés.

References

1. **Fouracre PR, Jacobs GD.** *Comparative accident costs in developing countries.* Crowthorne, Transport and Road Research Laboratory, 1976.
2. **International Road Federation.** *World road statistics 1987–1991.* Geneva, International Road Federation, 1992.
3. **Jacobs GD, Cutting CA.** Further research on accident rates in developing countries. *Accid. anal. prev.*, 1986, **18**: 119–127.
4. **Omran AR.** The epidemiologic transition: a theory of the epidemiology of population change. *Milbank Mem. Fund Q.*, 1971, **49**: 509–538.
5. **Ross A et al.** *Towards safer roads in developing countries—a guide for planners and engineers.* Crowthorne, Transport and Road Research Laboratory, 1991: 3.
6. **Smeed RJ.** Some statistical aspects of road safety research. *J. Royal Stat. Soc.*, 1949, **112**: 1–23.
7. **Smeed RJ.** The international comparison of accident rates. *Int. road traffic safety rev.*, 1953, **1**: 16–19.
8. **The National Committee for Injury Prevention.** Traffic injuries. In: *Injury prevention: meeting the challenge.* New York, Oxford University Press, 1989: 115–144.
9. **Wintemute GJ.** Is motor vehicle-related mortality a disease of development? *Accid. anal. prev.*, 1985, **17**: 223–237.
10. **Wintemute GJ.** Injury mortality and socioeconomic development: an exploratory analysis. *Int. j. epidemiol.*, 1986, **15**: 540–543.
11. **World Bank.** *World development report 1993—Investing in health.* New York, Oxford University Press, 1993.
12. **World Bank.** *World development report 1992—Development and the environment.* New York, Oxford University Press, 1992.
13. *Road traffic accident statistics* (Euro Reports and Studies, No. 19). Copenhagen, WHO Regional Office for Europe, 1979: 7.
14. *New approaches to improve road safety. Report of a WHO Study Group.* Geneva, World Health Organization, 1989 (WHO Technical Report Series, No. 781).
15. **Zwi AB.** Injury control in developing countries—Where are we now? *Health policy and planning*, 1993; **8**: 173–179.
16. **Zwi AB.** The public health burden of injury in developing countries: a critical review of the literature. *Tropical diseases bulletin*, 1993, **90**(4): R5–R45.